

**UNITED STATES PATENT APPLICATION**

---

**SERVICE SELECTION IN A SHARED ACCESS NETWORK  
USING DYNAMIC HOST CONFIGURATION PROTOCOL**

---

**INVENTORS:**

**John W. Garrett**

**Charles Robert Kalmanek Jr.**

**Han Q. Nguyen**

**Kadangode K. Ramakrishnan**

### **Cross Reference to Related Applications**

This application claims priority to United States Provisional Application Serial No. 60/190,633, entitled "INTERNET SERVICE SELECTION OVER CABLE," filed on March 20, 2000, and to United States Provisional Application Serial No. 60/190,636, entitled "QUALITY OF SERVICE OVER THE HFC CABLE PLANT," filed on March 20, 2000, the contents of which are incorporated by reference herein.

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60  
61  
62  
63  
64  
65  
66  
67  
68  
69  
70  
71  
72  
73  
74  
75  
76  
77  
78  
79  
80  
81  
82  
83  
84  
85  
86  
87  
88  
89  
90  
91  
92  
93  
94  
95  
96  
97  
98  
99  
100  
101  
102  
103  
104  
105  
106  
107  
108  
109  
110  
111  
112  
113  
114  
115  
116  
117  
118  
119  
120  
121  
122  
123  
124  
125  
126  
127  
128  
129  
130  
131  
132  
133  
134  
135  
136  
137  
138  
139  
140  
141  
142  
143  
144  
145  
146  
147  
148  
149  
150  
151  
152  
153  
154  
155  
156  
157  
158  
159  
160  
161  
162  
163  
164  
165  
166  
167  
168  
169  
170  
171  
172  
173  
174  
175  
176  
177  
178  
179  
180  
181  
182  
183  
184  
185  
186  
187  
188  
189  
190  
191  
192  
193  
194  
195  
196  
197  
198  
199  
200  
201  
202  
203  
204  
205  
206  
207  
208  
209  
210  
211  
212  
213  
214  
215  
216  
217  
218  
219  
220  
221  
222  
223  
224  
225  
226  
227  
228  
229  
230  
231  
232  
233  
234  
235  
236  
237  
238  
239  
240  
241  
242  
243  
244  
245  
246  
247  
248  
249  
250  
251  
252  
253  
254  
255  
256  
257  
258  
259  
260  
261  
262  
263  
264  
265  
266  
267  
268  
269  
270  
271  
272  
273  
274  
275  
276  
277  
278  
279  
280  
281  
282  
283  
284  
285  
286  
287  
288  
289  
290  
291  
292  
293  
294  
295  
296  
297  
298  
299  
300  
301  
302  
303  
304  
305  
306  
307  
308  
309  
310  
311  
312  
313  
314  
315  
316  
317  
318  
319  
320  
321  
322  
323  
324  
325  
326  
327  
328  
329  
330  
331  
332  
333  
334  
335  
336  
337  
338  
339  
340  
341  
342  
343  
344  
345  
346  
347  
348  
349  
350  
351  
352  
353  
354  
355  
356  
357  
358  
359  
360  
361  
362  
363  
364  
365  
366  
367  
368  
369  
370  
371  
372  
373  
374  
375  
376  
377  
378  
379  
380  
381  
382  
383  
384  
385  
386  
387  
388  
389  
390  
391  
392  
393  
394  
395  
396  
397  
398  
399  
400  
401  
402  
403  
404  
405  
406  
407  
408  
409  
410  
411  
412  
413  
414  
415  
416  
417  
418  
419  
420  
421  
422  
423  
424  
425  
426  
427  
428  
429  
430  
431  
432  
433  
434  
435  
436  
437  
438  
439  
440  
441  
442  
443  
444  
445  
446  
447  
448  
449  
450  
451  
452  
453  
454  
455  
456  
457  
458  
459  
460  
461  
462  
463  
464  
465  
466  
467  
468  
469  
470  
471  
472  
473  
474  
475  
476  
477  
478  
479  
480  
481  
482  
483  
484  
485  
486  
487  
488  
489  
490  
491  
492  
493  
494  
495  
496  
497  
498  
499  
500  
501  
502  
503  
504  
505  
506  
507  
508  
509  
510  
511  
512  
513  
514  
515  
516  
517  
518  
519  
520  
521  
522  
523  
524  
525  
526  
527  
528  
529  
530  
531  
532  
533  
534  
535  
536  
537  
538  
539  
540  
541  
542  
543  
544  
545  
546  
547  
548  
549  
550  
551  
552  
553  
554  
555  
556  
557  
558  
559  
560  
561  
562  
563  
564  
565  
566  
567  
568  
569  
570  
571  
572  
573  
574  
575  
576  
577  
578  
579  
580  
581  
582  
583  
584  
585  
586  
587  
588  
589  
590  
591  
592  
593  
594  
595  
596  
597  
598  
599  
600  
601  
602  
603  
604  
605  
606  
607  
608  
609  
610  
611  
612  
613  
614  
615  
616  
617  
618  
619  
620  
621  
622  
623  
624  
625  
626  
627  
628  
629  
630  
631  
632  
633  
634  
635  
636  
637  
638  
639  
640  
641  
642  
643  
644  
645  
646  
647  
648  
649  
650  
651  
652  
653  
654  
655  
656  
657  
658  
659  
660  
661  
662  
663  
664  
665  
666  
667  
668  
669  
670  
671  
672  
673  
674  
675  
676  
677  
678  
679  
680  
681  
682  
683  
684  
685  
686  
687  
688  
689  
690  
691  
692  
693  
694  
695  
696  
697  
698  
699  
700  
701  
702  
703  
704  
705  
706  
707  
708  
709  
710  
711  
712  
713  
714  
715  
716  
717  
718  
719  
720  
721  
722  
723  
724  
725  
726  
727  
728  
729  
730  
731  
732  
733  
734  
735  
736  
737  
738  
739  
740  
741  
742  
743  
744  
745  
746  
747  
748  
749  
750  
751  
752  
753  
754  
755  
756  
757  
758  
759  
760  
761  
762  
763  
764  
765  
766  
767  
768  
769  
770  
771  
772  
773  
774  
775  
776  
777  
778  
779  
780  
781  
782  
783  
784  
785  
786  
787  
788  
789  
790  
791  
792  
793  
794  
795  
796  
797  
798  
799  
800  
801  
802  
803  
804  
805  
806  
807  
808  
809  
810  
811  
812  
813  
814  
815  
816  
817  
818  
819  
820  
821  
822  
823  
824  
825  
826  
827  
828  
829  
830  
831  
832  
833  
834  
835  
836  
837  
838  
839  
840  
841  
842  
843  
844  
845  
846  
847  
848  
849  
850  
851  
852  
853  
854  
855  
856  
857  
858  
859  
860  
861  
862  
863  
864  
865  
866  
867  
868  
869  
870  
871  
872  
873  
874  
875  
876  
877  
878  
879  
880  
881  
882  
883  
884  
885  
886  
887  
888  
889  
890  
891  
892  
893  
894  
895  
896  
897  
898  
899  
900  
901  
902  
903  
904  
905  
906  
907  
908  
909  
910  
911  
912  
913  
914  
915  
916  
917  
918  
919  
920  
921  
922  
923  
924  
925  
926  
927  
928  
929  
930  
931  
932  
933  
934  
935  
936  
937  
938  
939  
940  
941  
942  
943  
944  
945  
946  
947  
948  
949  
950  
951  
952  
953  
954  
955  
956  
957  
958  
959  
960  
961  
962  
963  
964  
965  
966  
967  
968  
969  
970  
971  
972  
973  
974  
975  
976  
977  
978  
979  
980  
981  
982  
983  
984  
985  
986  
987  
988  
989  
990  
991  
992  
993  
994  
995  
996  
997  
998  
999  
1000  
1001  
1002  
1003  
1004  
1005  
1006  
1007  
1008  
1009  
1010  
1011  
1012  
1013  
1014  
1015  
1016  
1017  
1018  
1019  
1020  
1021  
1022  
1023  
1024  
1025  
1026  
1027  
1028  
1029  
1030  
1031  
1032  
1033  
1034  
1035  
1036  
1037  
1038  
1039  
1040  
1041  
1042  
1043  
1044  
1045  
1046  
1047  
1048  
1049  
1050  
1051  
1052  
1053  
1054  
1055  
1056  
1057  
1058  
1059  
1060  
1061  
1062  
1063  
1064  
1065  
1066  
1067  
1068  
1069  
1070  
1071  
1072  
1073  
1074  
1075  
1076  
1077  
1078  
1079  
1080  
1081  
1082  
1083  
1084  
1085  
1086  
1087  
1088  
1089  
1090  
1091  
1092  
1093  
1094  
1095  
1096  
1097  
1098  
1099  
1100  
1101  
1102  
1103  
1104  
1105  
1106  
1107  
1108  
1109  
1110  
1111  
1112  
1113  
1114  
1115  
1116  
1117  
1118  
1119  
1120  
1121  
1122  
1123  
1124  
1125  
1126  
1127  
1128  
1129  
1130  
1131  
1132  
1133  
1134  
1135  
1136  
1137  
1138  
1139  
1140  
1141  
1142  
1143  
1144  
1145  
1146  
1147  
1148  
1149  
1150  
1151  
1152  
1153  
1154  
1155  
1156  
1157  
1158  
1159  
1160  
1161  
1162  
1163  
1164  
1165  
1166  
1167  
1168  
1169  
1170  
1171  
1172  
1173  
1174  
1175  
1176  
1177  
1178  
1179  
1180  
1181  
1182  
1183  
1184  
1185  
1186  
1187  
1188  
1189  
1190  
1191  
1192  
1193  
1194  
1195  
1196  
1197  
1198  
1199  
1200  
1201  
1202  
1203  
1204  
1205  
1206  
1207  
1208  
1209  
1210  
1211  
1212  
1213  
1214  
1215  
1216  
1217  
1218  
1219  
1220  
1221  
1222  
1223  
1224  
1225  
1226  
1227  
1228  
1229  
1230  
1231  
1232  
1233  
1234  
1235  
1236  
1237  
1238  
1239  
1240  
1241  
1242  
1243  
1244  
1245  
1246  
1247  
1248  
1249  
1250  
1251  
1252  
1253  
1254  
1255  
1256  
1257  
1258  
1259  
1260  
1261  
1262  
1263  
1264  
1265  
1266  
1267  
1268  
1269  
1270  
1271  
1272  
1273  
1274  
1275  
1276  
1277  
1278  
1279  
1280  
1281  
1282  
1283  
1284  
1285  
1286  
1287  
1288  
1289  
1290  
1291  
1292  
1293  
1294  
1295  
1296  
1297  
1298  
1299  
1300  
1301  
1302  
1303  
1304  
1305  
1306  
1307  
1308  
1309  
1310  
1311  
1312  
1313  
1314  
1315  
1316  
1317  
1318  
1319  
1320  
1321  
1322  
1323  
1324  
1325  
1326  
1327  
1328  
1329  
1330  
1331  
1332  
1333  
1334  
1335  
1336  
1337  
1338  
1339  
1340  
1341  
1342  
1343  
1344  
1345  
1346  
1347  
1348  
1349  
1350  
1351  
1352  
1353  
1354  
1355  
1356  
1357  
1358  
1359  
1360  
1361  
1362  
1363  
1364  
1365  
1366  
1367  
1368  
1369  
1370  
1371  
1372  
1373  
1374  
1375  
1376  
1377  
1378  
1379  
1380  
1381  
1382  
1383  
1384  
1385  
1386  
1387  
1388  
1389  
1390  
1391  
1392  
1393  
1394  
1395  
1396  
1397  
1398  
1399  
1400  
1401  
1402  
1403  
1404  
1405  
1406  
1407  
1408  
1409  
1410  
1411  
1412  
1413  
1414  
1415  
1416  
1417  
1418  
1419  
1420  
1421  
1422  
1423  
1424  
1425  
1426  
1427  
1428  
1429  
1430  
1431  
1432  
1433  
1434  
1435  
1436  
1437  
1438  
1439  
1440  
1441  
1442  
1443  
1444  
1445  
1446  
1447  
1448  
1449  
1450  
1451  
1452  
1453  
1454  
1455  
1456  
1457  
1458  
1459  
1460  
1461  
1462  
1463  
1464  
1465  
1466  
1467  
1468  
1469  
1470  
1471  
1472  
1473  
1474  
1475  
1476  
1477  
1478  
1479  
1480  
1481  
1482  
1483  
1484  
1485  
1486  
1487  
1488  
1489  
1490  
1491  
1492  
1493  
1494  
1495  
1496  
1497  
1498  
1499  
1500  
1501  
1502  
1503  
1504  
1505  
1506  
1507  
1508  
1509  
1510  
1511  
1512  
1513  
1514  
1515  
1516  
1517  
1518  
1519  
1520  
1521  
1522  
1523  
1524  
1525  
1526  
1527  
1528  
1529  
1530  
1531  
1532  
1533  
1534  
1535  
1536  
1537  
1538  
1539  
1540  
1541  
1542  
1543  
1544  
1545  
1546  
1547  
1548  
1549  
1550  
1551  
1552  
1553  
1554  
1555  
1556  
1557  
1558  
1559  
1560  
1561  
1562  
1563  
1564  
1565  
1566  
1567  
1568  
1569  
1570  
1571  
1572  
1573  
1574  
1575  
1576  
1577  
1578  
1579  
1580  
1581  
1582  
1583  
1584  
1585  
1586  
1587  
1588  
1589  
1590  
1591  
1592  
1593  
1594  
1595  
1596  
1597  
1598  
1599  
1600  
1601  
1602  
1603  
1604  
1605  
1606  
1607  
1608  
1609  
1610  
1611  
1612  
1613  
1614  
1615  
1616  
1617  
1618  
1619  
1620  
1621  
1622  
1623  
1624  
1625  
1626  
1627  
1628  
1629  
1630  
1631  
1632  
1633  
1634  
1635  
1636  
1637  
1638  
1639  
1640  
1641  
1642  
1643  
1644  
1645  
1646  
1647  
1648  
1649  
1650  
1651  
1652  
1653  
1654  
1655  
1656  
1657  
1658  
1659  
1660  
1661  
1662  
1663  
1664  
1665  
1666  
1667  
1668  
1669  
1670  
1671  
1672  
1673  
1674  
1675  
1676  
1677  
1678  
1679  
1680  
1681  
1682  
1683  
1684  
1685  
1686  
1687  
1688  
1689  
1690  
1691  
1692  
1693  
1694  
1695  
1696  
1697  
1698  
1699  
1700  
1701  
1702  
1703  
1704  
1705  
1706  
1707  
1708  
1709  
1710  
1711  
1712  
1713  
1714  
1715  
1716  
1717  
1718  
1719  
1720  
1721  
1722  
1723  
1724  
1725  
1726  
1727  
1728  
1729  
1730  
1731  
1732  
1733  
1734  
1735  
1736  
1737  
1738  
1739  
1740  
1741  
1742  
1743  
1744  
1745  
1746  
1747  
1748  
1749  
1750  
1751  
1752  
1753  
1754  
1755  
1756  
1757  
1758  
1759  
1760  
1761  
1762  
1763  
1764  
1765  
1766  
1767  
1768  
1769  
1770  
1771  
1772  
1773  
1774  
1775  
1776  
1777  
1778  
1779  
1780  
1781  
1782  
1783  
1784  
1785  
1786  
1787  
1788  
1789  
1790  
1791  
1792  
1793  
1794  
1795  
1796  
1797  
1798  
1799  
1800  
1801  
1802  
1803  
1804  
1805  
1806  
1807  
1808  
1809  
1810  
1811  
1812  
1813  
1814  
1815  
1816  
1817  
1818  
1819  
1820  
1821  
1822  
1823  
1824  
1825  
1826  
1827  
1828  
1829  
1830  
1831  
1832  
1833  
1834  
1835  
1836  
1837  
1838  
1839  
1840  
1841  
1842  
1843  
1844  
1845  
1846  
1847  
1848  
1849  
1850  
1851  
1852  
1853  
1854  
1855  
1856  
1857  
1858  
1859  
1860  
1861  
1862  
1863  
1864  
1865  
1866  
1867  
1868  
1869  
1870  
1871  
1872  
1873  
1874  
1875  
1876  
1877  
1878  
1879  
1880  
1881  
1882  
1883  
1884  
1885  
1886  
1887  
1888  
1889  
1890  
1891  
1892  
1893  
1894  
1895  
1896  
1897  
1898  
1899  
1900  
1901  
1902  
1903  
1904  
1905  
1906  
1907  
1908  
1909  
1910  
1911  
1912  
1913  
1914  
1915  
1916  
1917  
1918  
1919  
1920  
1921  
1922  
1923  
1924  
1925  
1926  
1927  
1928  
1929  
1930  
1931  
1932  
1933  
1934  
1935  
1936  
1937  
1938  
1939  
1940  
1941  
1942  
1943  
1944  
1945  
1946  
1947  
1948  
1949  
1950  
1951  
1952  
1953  
1954  
1955  
1956  
1957  
1958  
1959  
1960  
1961  
1962  
1963  
1964  
1965  
1966  
1967  
1968  
1969  
1970  
1971  
1972  
1973  
1974  
1975  
1976  
1977  
1978  
1979  
1980  
1981  
1982  
1983  
1984  
1985  
1986  
1987  
1988  
1989  
1990  
1991  
1992  
1993  
1994  
1995  
1996  
1997  
1998  
1999  
2000  
2001  
2002  
2003  
2004  
2005  
2006  
2007  
2008  
2009  
2010  
2011  
2012  
2013  
2014  
2015  
2016  
2017  
2018  
2019  
2020  
2021  
2022  
2023  
2024  
2025  
2026  
2027  
2028  
2029  
2030  
2031  
2032  
2033  
2034  
2035  
2036  
2037  
2038  
2039  
2040  
2041  
2042  
2043  
2044  
2045  
2046  
2047  
2048  
2049  
2050  
2051  
2052  
2053  
2054  
2055  
2056  
2057  
2058  
2059  
2060  
2061  
2062  
2063  
2064  
2065  
2066  
2067  
2068  
2069  
2070  
2071  
2072  
2073  
2074  
2075  
2076  
2077  
2078  
2079  
2080  
2081  
2082  
2083  
2084  
2085  
2086  
2087  
2088  
2089  
2090  
2091  
2092  
2093  
2094  
2095  
2096  
2097  
2098  
2099  
2100  
2101  
2102  
2103  
2104  
2105  
2106  
2107  
2108  
2109  
2110  
2111  
2112  
2113  
2114  
2115  
2116  
2117  
2118  
2119  
2120  
2121  
2122  
2123  
2124  
2125  
2126  
2127  
2128  
2129  
2130  
2131  
2132  
2133  
2134  
2135  
2136  
2137  
2138  
2139  
2140  
2141  
2142  
2143  
2144  
2145  
2146  
2147  
2148  
2149  
2150  
2151  
2152  
2153  
2154  
2155  
2156  
2157  
2158  
2159  
2160  
2161  
2162  
2163  
2164  
2165  
2166  
2167  
2168  
2169  
2170  
2171  
2172  
2173  
2174  
2175  
2176  
2177  
2178  
2179  
2180  
2181  
2182  
2183  
2184  
2185  
2186  
2187  
2188  
2189  
2190  
2191  
2192  
2193  
2194  
2195  
2196  
2197  
2198  
2199  
2200  
2201  
2202  
2203  
2204  
2205  
22

## **SERVICE SELECTION IN A SHARED ACCESS NETWORK USING DYNAMIC HOST CONFIGURATION PROTOCOL**

### **Field of the Invention**

5                   The present invention relates generally to communication network services, and, more particularly, to providing multiple services in a communication network.

### **Background of the Invention**

10                   Customers of communication network services often desire access to a plurality of different services and different service providers. For example, when using a dial-up connection to a packet-switched data network such as the Internet, a customer can choose from multiple service providers by dialing different telephone numbers in the PSTN. The physical path from the customer to  
15                   the customer's Internet Service Provider (ISP) is dedicated to the connection for the duration of the telephone call. The ISP assigns an IP address to the customer and can link the authenticated customer and the assigned IP address to the physical address (e.g. dial-up modem) used by the customer. With this linkage, the ISP can ensure the customer only uses the address authorized by the ISP and  
20                   can use the customer's IP address to manage access to the ISP's services. The physical connection between a customer and the ISP, as well as the linkage to IP address assignment and customer authentication is terminated when the dial-up connection is terminated.

                  Constrained by the physical capacity of these temporary  
25                   connections across the PSTN, many service providers are moving to high-speed access architectures (e.g., digital subscriber line (DSL), wireless, satellite, or cable) that provide dedicated physical connectivity directly to the subscriber and under the control of the ISP. These alternatives to shared access through the switched telephone network, however, do not lend themselves to shared access by  
30                   multiple services and/or service providers.

## Summary of the Invention

It is an object of the invention to enable multiple services or service providers to share the facilities of an access network infrastructure providing physical connectivity to subscribers. In accordance with an embodiment of the invention, a router situated at an edge of an access network forwards packets to any of a plurality of packet-switched service networks. The router uses a policy based on the source address of the packets to determine to which service network to forward the packet. Each network access device is assigned a network address, which is associated with a particular service or service provider to which the user of the device is subscribed. The network access device advantageously may be used in communication network services with a service or service provider that is separate from the operator of the access network infrastructure.

In accordance with another aspect of the invention, interconnections between a plurality of packet-switched service networks and an access network are localized into managed access points. Routers in the access network can advantageously forward packets to the managed access points using conventional routing procedures, thus enabling the access network to provide "local" packet-switched services. The managed access points use source address-based policy to determine to which service network to forward a packet. Where a packet arrives at a managed access point that is not connected to the correct service network, the managed access point can use packet encapsulation or some other form of tunneling to redirect the packet to the correct managed access point. The present invention, among other advantages, does not require interconnection points to each service network at every regional access network site.

In accordance with another aspect of the invention, a configuration server, upon receiving a request from a network access device selecting a particular service, allocates a network address from a pool of addresses associated with the service and assigns the network address to the network access device using a host configuration protocol, such as DHCP. In accordance with an embodiment of the invention, the configuration server authenticates the network

access device before assigning a network address. In accordance with another embodiment of the invention, the configuration server transmits authentication information received from the network access device to a server in the service network responsible for authentication. In accordance with another embodiment of the invention, the host configuration protocol messages acknowledging allocation of a network address to the service subscriber's network access device are used to create entries in an address resolution protocol cache in order to restrict access to the access network infrastructure to those network access devices that are properly registered and authenticated. In accordance with another embodiment of the invention, the host configuration protocol acknowledging allocation of the network address to the service subscriber's network access device are used to initiate the distribution of service policies to policy enforcement points in order to enable differentiated quality-of-support for different subscribers of different services or service providers. The present invention, among other advantages, enables the network addresses—which ultimately determine the service network utilized by the particular network access device—to be allocated and reassigned dynamically.

These and other advantages of the invention will be apparent to those of ordinary skill in the art by reference to the following detailed description and the accompanying drawings.

### **Brief Description of the Drawings**

FIG. 1 illustrates an interconnection of packet-switched service networks and an access network embodying principles of the invention.

FIG. 2A and FIG. 2B is conceptual representation of an example embodiment illustrating principles of the invention based on an HFC access architecture with corresponding end-to-end protocol layers.

FIG. 3 is a flowchart of processing performed at a policy router, in accordance with an embodiment of the invention.

FIG. 4 is a simplified example of router configuration instructions.

FIG. 5 illustrates an interconnection of packet-switched service network, regional access networks, and a packet-switched access network,  
95 embodying principles of another aspect of the invention.

FIG. 6 is a flowchart of processing performed at a policy router acting as a managed access point, in accordance with another embodiment of the invention.

FIG. 7 is a timeline diagram of messages exchanged in the  
100 assignment of a network address associated with a particular service to a network access device, in accordance with a preferred embodiment of another aspect of the invention.

FIG. 8 is a conceptual representation of a DHCP message exchanged between the network access device and a DHCP server.

FIG. 9 is timeline diagram of messages exchanged in the  
105 assignment of a network address associated with a particular service to a network access device, in accordance with a preferred embodiment of another aspect of the invention.

FIG. 10 is a timeline diagram of messages exchanged in the  
110 assignment of a network address associated with a particular service to a network access device, in accordance with a preferred embodiment of another aspect of the invention.

FIG. 11 is a flowchart of processing performed at a Cable Modem Termination System, exemplifying an embodiment of another aspect of the  
115 invention.

FIG. 12 is a timeline diagram of messages exchanged in the assignment of a service class to a subscriber, in accordance with a preferred embodiment of another aspect of the invention.

FIG. 13 is a conceptual diagram of a hierarchical link-sharing  
120 structure.

### Detailed Description

In FIG. 1, a plurality of subscribers operating network access devices 101, 102, 103, ... 104 are provided access to communication network services, which are facilitated by a plurality of packet-switched data networks, shown in FIG. 1 as 151 and 152. Packet-switched data networks 151 and 152, referred to herein as "service networks," offer access to different services and/or are operated by different service providers. For example, service network 151 could provide packet-switched connectivity to public data networks while service network 152 could offer packet-switched telephony service (or the same public data network connectivity, but from a different service provider). The service networks, as is well known in the art, utilize a network addressing scheme to route datagrams to and from hosts: for example, where the service networks utilize the TCP/IP protocol suite, Internet Protocol (IP) addresses are assigned to each host and utilized in the process of routing packets from a source to a destination in the networks. See, e.g., "INTERNET PROTOCOL," IETF Network Working Group, RFC 791 (September 1981); S. Deering, R. Hinden, "Internet Protocol, Version 6 (IPv6) Specification," IETF Network Working Group, RFC 1883 (December 1995), which are incorporated by reference herein. The invention shall be described herein with particular reference to the TCP/IP protocol suite and IP addresses, although those skilled in the art would readily be able to implement the invention using any of a number of different communication protocols.

The network access devices 101 ... 104 are typically customer premises equipment (CPE) such as a personal computer, information appliance, personal data assistant, data-enabled wireless handset, or any other type of device capable of accessing information through a packet-switched data network. Each network access device 101 ... 104 is either connected to or integrated with a network interface unit 111 ... 114, e.g. a modem, which enables communication through an access network infrastructure, shown as 120 in FIG. 1. Each network access device is assigned an IP address which, in accordance with an aspect of the invention, is associated with a particular service or service provider to which the user of the device is subscribed. For example, network access device 101 is

assumed to have been assigned, for purposes of the description herein, an IP address associated with a service provider operating service network 151. As  
 155 further described herein, it is advantageous to provide a service activation system 160 which advantageously permits the dynamic allocation, assignment, and reassignment of IP addresses to the plurality of network access devices based on customer subscriptions to particular services.

The network access device 101 communicates with the service  
 160 network 151 through the access network infrastructure 120, which, in accordance with aspects of the invention, is capable of recognizing and directing traffic to the proper service network. The access network infrastructure 120 advantageously can be operated and maintained by an entity that is the same as or different from the entities operating and maintaining the service networks 151 and 152. In  
 165 accordance with an embodiment of an aspect of the present invention, the different IP-based services offered by the different service networks 151 and 152 utilize shared layer one and layer two resources in the access network 120. Layer three routing procedures, however, are modified to permit IP traffic from network access device 101 to flow to the correct subscribed service network 151. The  
 170 access network 120 has a router 130 on the edge of the access network. The router 130 has a first interface with a connection to a router 141 in service network 151 and a second interface with a connection to a router 142 in service network 152. As further described herein, the router processes packets and is capable of directing traffic to the proper service network.

175 FIG. 2A shows an exemplary access architecture based on a hybrid fiber coaxial (HFC) access network. As is known in the art, each network interface device 201 ... 202 is either connected to or integrated with a cable modem 211 which enables communication through the HFC network 221. In accordance with the Data Over Cable Service Interface Specification (DOCSIS), a  
 180 Cable Modem Termination System (CMTS), shown as 225 in FIG. 2A, communicates with the cable modems 211 and manages access to both upstream and downstream cable capacity on the HFC networks 221. See, e.g., "Data-Over-Cable Service Interface Specifications: Cable Modem Termination System --



Network Side Interface Specification,” Cable Television Laboratories, Inc., SP-  
 185 CMTS-NSI-I01-960702; “Data-Over-Cable Service Interface Specifications:  
 Cable Modem to Customer Premise Equipment Interface Specification,” Cable  
 Television Laboratories, Inc., SP-CMCI-C02C-991015; “Data-Over-Cable  
 Service Interface Specifications: Baseline Privacy Plus Interface Specifications,”  
 Cable Television Laboratories, Inc., SP-BPI+-I06-001215, which are incorporated  
 190 by reference herein. The CMTS 225 manages the scheduling of both upstream  
 and downstream transmission and allocates cable capacity to individual customers  
 identified by a Service IDs (SIDs). The CMTS 225 can have an integrated router  
 228 or can be a separate device 226 that bridges to a fast Ethernet switch 227  
 which connects to the router 228. The IP router 228 provides connectivity to an  
 195 IP network 222, which further comprises the router 230 (corresponding to router  
 130 in FIG. 1) which interfaces to IP routers 241 and 242 in service networks 251  
 and 252, respectively. Accordingly, the HFC network 221, the CMTS 225, and  
 the IP network 222 correspond to the access network infrastructure 120 shown in  
 FIG. 1. FIG. 2B shows a conceptual diagram of the end-to-end communication  
 200 protocol stack from a network access device 201 (101) to a router 241 (141) in  
 service provider’s network 251 (151). As is known in the art, the lowest layer  
 deals with the physical layer (PL) of the protocol stack, e.g. the Ethernet physical  
 media device (PMD) layer; the second layer deals with the data link layer, e.g. the  
 Ethernet Media Access Control (MAC) layer; and the third layer in the protocol  
 205 stack deals with the network layer, e.g. the IP layer. The following aspects of the  
 invention deal with modifications to routing processes in the network layer of the  
 protocol stack.

Router 130 in the access network 120 in FIG. 1 (corresponding to  
 IP router 230 in FIG. 2) separates the IP traffic to the multiple services or service  
 210 providers as well as combines traffic from the multiple services or service  
 providers. In accordance with an aspect of the invention, IP packets are routed  
 from network access device 101 to the subscribed service network 151 using  
 source address-based policy routing. Conventional routing is destination-based:  
 the router consults an internal routing table which maps the destination addresses

215 of all inbound packets to a physical interface address for use for outgoing packets. Policy routing schemes, however, will selectively choose different paths for different packets even where the packet's destination address may be the same. Since network access devices are assigned addresses associated with a particular network service provider, the source address based policy routing scheme ensures  
 220 packets from a network access device will go to the appropriate service network. Conventional destination-based routing will ensure that packets addressed to a network access device will be routed to the appropriate service network. Note that this would require service providers to advertise their service address ranges to their peers.

225 FIG. 3 sets forth the processing performed at a router in the access network, e.g. router 130 in FIG. 1. At step 301, the router receives an incoming packet. At step 302, the router reads the packet header and retrieves the packet filtering rules, typically stored in an access list as further described below. At steps 303, 305, and 307, the router applies the packet filtering rules. At step 303,  
 230 the router compares the source IP address in the packet header to a list of addresses allocated to subscribers of services of a first service provider, e.g. operating service network 151 in FIG. 1. If the source address matches one of these addresses, then at step 304 the router forwards the packet to a router in service network 151, e.g. router 141 in FIG. 1. At step 305, the router compares  
 235 the source IP address in the packet header to a list of addresses allocated to subscribers of services of a second service provider, e.g. operating service network 152 in FIG. 1. If the source IP address matches one of these addresses, then at step 305 the router forwards the packet to a router in service network 152, e.g. router 142 in FIG. 1. The router continues in this fashion with any other  
 240 packet filtering rules identifying IP addresses allocated to subscribers of any other service providers. Assuming the IP source address does not match any such addresses associated with a service provider, at step 307, the router applies any remaining packet filtering rules and routes or denies the packet accordingly.

FIG. 4 sets forth an example of router configuration instructions  
 245 written for the Cisco Internetworking Operating System (IOS), which is used

pervasively on conventional IP routers. Only the relevant portions of the configuration instructions are shown. Lines 401 to 405 configure the interface to utilize policy routing. Lines 406 to 410 specify the particular policy, namely to set the next “hop” address to the router address of a router in a one of the service networks, i.e. “isp1\_next-hop\_address,” if the source address matches a range of addresses allocated to subscribers of the services provided by the service network, i.e. “isp1\_subs.” Lines 412 to 413 set forth access lists associating “isp1\_subs” with ranges of addresses expressed, by convention, as a source address and a mask portion, i.e., the above policy is applied by the router to any traffic with a subscriber source address expressed as “isp1\_prefix1” with a mask portion of “isp1\_prefix1\_wildcard”.

The embodiment shown in FIG. 1 notably requires interconnection points to all relevant service networks at each edge of each regional access network. In accordance with another aspect of the invention, it is desirable to create a regional transport network of routers and to localize the interconnection between the service networks and the access infrastructure into managed access points. A managed access point is a physical location at which the interfaces to the service networks can be provided. Having one or a small plurality of managed access points advantageously allows service selection to be implemented without requiring network service providers to connect physical facilities into, for example, every cable head end in an HFC-based network—thereby reducing costs for both the access network infrastructure operator and the service network providers. Each router in the regional transport network can be configured with policy information and invoke source address routing to forward packets to the managed access point providing access to the relevant service network. By overriding normal routing procedures, however, these procedures may introduce potential routing loops absent significant coordination between the routers external to known routing protocols. This risk can be minimized by centralizing the policy routing function in a single router that provides the interfaces to the service networks.

FIG. 5 illustrates an embodiment of this aspect of the invention.

Each network access device 501 is connected through a network interface unit 511 to one of a plurality of access networks, e.g. 521 and 522 in FIG. 5. Each access network has an edge router (531 and 532 respectively in FIG. 5) which connects  
 280 the access network to a regional IP network of routers, represented abstractly in FIG. 5 as IP access network 570. It is advantageous to aggregate connections from groups of edge routers to a single aggregation router 571 in the IP access network 570, as shown in FIG. 5. Aggregation router 571 can then connect to other routers in the regional IP network 570, i.e. routers 572 ... 573, which can  
 285 also be aggregation routers connecting to pluralities of edge routers. Routers 541, 542, ... 543 in service networks 551, 552, ... 553 connect to the IP network 570 at routers 574 and 575, which act as managed access points to the service networks. Only the managed access point routers, e.g. 575, need invoke policy routing based on packet source address. All intermediate routers within the IP access network  
 290 570, i.e. 571 ... 573, use normal destination-based forwarding procedures for destinations that are not local to the network 570. No configuration of policy in the intermediate routers is necessary.

By locating the policy routing functions at the interfaces to the service networks, the access network infrastructure (whether reflected generally  
 295 by 120 in FIG. 1 or, in the packet-switched context, as network 570 in FIG. 5) can provide access to "local" services available from within the access network infrastructure. For example, IP network 570 can provide access to "local" packet-switched services and operate independent of the source address assigned to the network access devices. Since the intermediate routers 571 ... 573 all use  
 300 conventional destination-based forwarding, network 570 will properly route local service packets along the correct routing paths. "Non-local" service packets, however, are routed towards the managed access point routers 575 and 574 and policy routed to the correct service network. Where the network 570 forwards to a single managed access point router or where each managed access point router  
 305 has a connection to each service network, the managed access point router can forward packets in accordance with the policies described above. Where,

however, there are service networks that connect to only a subset of the managed access points (e.g., in FIG. 5, where service network 553 only connects to managed access point router 574), packets can be redirected or “tunneled” to the correct managed access point in order to ensure that the packets arrive at the correct service network. The multiple interconnected managed access points can then provide a single “logical” inter-domain gateway, again permitting all other routers to use conventional destination-based routing procedures.

FIG. 6 sets forth a flowchart of the processing performed at a managed access point router, e.g. router 575 in FIG. 5, illustrating an embodiment of this aspect of the invention. The particular managed access point router 575 is assumed to be connected to two service networks, e.g. service networks 551 and 552 in FIG. 5, while a second managed access point router 574 provides access to a third service network, service network 553. At step 601, the router receives an incoming packet. At step 602, the router reads the packet header and retrieves the packet filtering rules, as well as decapsulates any encapsulated packets, as further described herein. At steps 603, 605, 607, and 609, the router applies the packet filtering rules. At step 603, the router compares the source IP address in the packet header to a list of addresses allocated to subscribers of services of a first service provider, e.g. operating service network 551 in FIG. 5. If the source address matches one of these addresses, then at step 604 the router forwards the packet to a router in service network 551, e.g. router 541 in FIG. 5. At step 605, the router compares the source IP address in the packet header to a list of addresses allocated to subscribers of services of a second service provider, e.g. operating service network 552 in FIG. 5. If the source IP address matches one of these addresses, then at step 606 the router forwards the packet to a router in service network 552, e.g. router 542 in FIG. 5. At step 607, the router compares the source IP address in the packet header to a list of addresses allocated to subscribers of services of a third service provider, e.g. operating service network 553 in FIG. 5, which is not connected to this particular managed access point. If the source IP address matches one of these addresses, then at step 608, the router encapsulates the packet, using any of a number of known methods for packet

encapsulation, and routes the packet to a new destination address, namely the address of the managed access point with access to service network 553, i.e. managed access point router 574. Packet encapsulation is a method by which a packet may rerouted to an intermediate destination other than the destination that would be selected using normal routing procedures. See, e.g., C. Perkins, "IP Encapsulation within IP," IETF Network Working Group, RFC 2003 (October 1996); C. Perkins, "Minimal Encapsulation within IP," IETF Network Working Group, RFC 2004 (October 1996), which are incorporated by reference herein. The receiving router 574 will decapsulate the packet and route the packet, accordingly, to service network 553. The router continues in this fashion with any other packet filtering rules identifying IP addresses associated with any other service providers. Assuming the IP source address does not match any addresses associated with any other service providers, at step 609, the router applies any remaining packet filtering rules and routes or denies the packet accordingly. Note that if managed access point 575 has a direct physical connection to managed access point 574, then no encapsulation is needed. In fact, a typical configuration might include multiple port-constrained policy routers on a GIG Ethernet providing the logical managed access point function without any encapsulation. Encapsulation is only really needed to provide a logical direct connection if there is not a direct physical connection.

Packets traveling between network access devices connected to the same access network infrastructure can be forwarded directly between the devices in the access network – rather than forwarding the packets outwards to a service network and back to the same access network. This advantageously saves on bandwidth and other network resources. The only packets that need be routed to a managed access point router need be the ones for which no specific route is known internally to the access network infrastructure.

It is advantageous to enable the IP addresses—which ultimately determine the service network utilized by the particular network access device—to be allocated and reassigned dynamically. With reference to FIG. 1, a service activation system 160 is shown which further comprises a configuration server

161 and a registration server 162 connected to the access network infrastructure  
 370 120. The registration server 162 provides a network-based  
 subscription/authorization process for the various services shared on the access  
 network infrastructure 120. A customer desiring to subscribe to a new service can  
 access and provide registration information to the registration server 162, e.g. by  
 using HTML forms and the Hyper Text Transfer Protocol (HTTP) as is known in  
 375 the art. Upon successful service subscription, the registration server 162 updates a  
 customer registration database 163. The configuration server 161 uses the  
 registration information to activate the service. The configuration server 161 is  
 responsible for allocating network addresses on behalf of the service networks  
 from a network address space associated with the selected service. In a preferred  
 380 embodiment of this aspect of the invention, the configuration server 161 uses a  
 host configuration protocol such as the Dynamic Host Configuration Protocol  
 (DHCP) to configure the network addresses of the network access devices. See  
 R. Droms, "Dynamic Host Configuration Protocol," IETF Network Working  
 Group, RFC 2131 (March 1997); S. Alexander, R. Droms, "DHCP Options and  
 385 BOOTP Vendor Extensions," IETF Network Working Group, RFC 2132 (March  
 1997); which are incorporated by reference herein. This aspect of the invention  
 shall be described herein with particular reference to DHCP, and the configuration  
 server 161 shall be referred to herein as the DHCP server, although those skilled  
 in the art would readily be able to implement this aspect of the invention using a  
 390 different protocol.

FIG. 7 is a simplified timeline diagram of DHCP messages  
 exchanged as the DHCP server 720 assigns a service-specific network address to a  
 network access device 710 acting as a DHCP client. At 701, the network access  
 device 710 sends a DHCPDISCOVER message through the access network  
 395 infrastructure. The DHCPDISCOVER message, in accordance with an aspect of  
 the invention, includes a "svc-id" option field that identifies the service to which  
 the network access device has been subscribed and from which service is desired.  
 The DHCP server 720 receives the DHCPDISCOVER message and, at 702,  
 allocates an IP address from the pool of addresses associated with the particular

400 service. The DHCP server 720 can use the device's MAC address to lookup the customer's registration information and confirm that the device is authorized to access the identified service. Where the DHCP server 720 cannot find the device's MAC address in the registration database, the server can allocate a special IP address that only allows access to the registration server. At 703, the  
 405 DHCP server 720 responds with a DHCPOFFER message that includes the IP address in a field in the DHCP message. At 704, the network access device 710 receives the DHCPOFFER (and any other offers from any other DHCP servers in the access network) and sends out a DHCPREQUEST directed to the DHCP server which requests the IP address identified in the DHCPOFFER. At 707, the  
 410 DHCP server commits to assigning the IP address to the network access device, commits the binding to persistent storage, and transmits a DHCPACK message containing the configuration parameters for the device. If the DHCP server is unable to satisfy the DHCPREQUEST message, the server responds with a DHCPNAK message. FIG. 8 is a simplified representation of the fields in a  
 415 DHCP message, including a "svc-id" option field (820) which identifies the selected service.

It is preferable that the DHCP servers and clients use some mutual authentication mechanism to restrict address assignment to authorized hosts and to prevent clients from accepting addresses from invalid DHCP servers. See, for  
 420 example, the "delayed authentication" scheme described in R. Droms, W. Arbaugh, "Authentication for DHCP Messages," IETF Network Working Group, Internet Draft, <draft-ietf-dhc-authentication-\_\_.txt>; or the Kerberos-based authentication mechanism described in K. Hornstein, T. Lemon, B. Aboba, J. Trostle, "DHCP Authentication via Kerberos V," IETF Network Working Group,  
 425 Internet Draft, <draft-hornstein-dhc-kerbauth-\_\_>; which are incorporated by reference herein. The "delayed authentication" mechanism supports mutual authentication of DHCP clients and servers based on a shared secret, which may be provisioned using out-of-band mechanisms. On the other hand, the Kerberos-based mechanisms are very well suited for inter-realm authentication, thereby  
 430 supporting client mobility, i.e. a network access device could connect to a



particular access network infrastructure without any prior registration with the access network. Each service network provider could securely authenticate the network access device accessing the service network from another network “realm,” e.g. the access network infrastructure.

435           The operator of the relevant service network, e.g. service network 152 in FIG. 1, may desire to maintain a separate registration server, e.g. server 155 in FIG. 1, and to retain responsibility for user authentication and authorization. The service activation system 160 can provide a proxy server configured to permits HTTP traffic only between local hosts and registration

440 server 155 in service network 152. The service provider operating service network 152 would then be responsible for providing the appropriate registration information required for proper service selection to the service activation system 160. The service provider would also be responsible for notifying the service activation system 160 when service should be discontinued. Alternatively, the

445 DHCP server 161 in the service activation system 160 can interact with the registration server 155 using a back-end authentication protocol, e.g. the Remote Authentication Dial In User Service (RADIUS). See C. Rigney, A. Rubens, W. Simpson, S. Willens, “Remote Authentication Dial In User Service (RADIUS),” IETF Network Working Group, RFC 2058 (January 1997), which is incorporated

450 by reference herein. The DHCP server can contain a RADIUS client and, thereby, leverage the large RADIUS embedded base used for dial access authentication. FIG. 9 illustrates this embodiment of this aspect of the invention in a flowchart corresponding to the flowchart shown in FIG. 7. At 903, the DHCP server 920 generates a random challenge and includes the challenge along with the allocated

455 IP address in the DHCPOFFER message. The DHCP client 910 generates a response to the challenge by encrypting the challenge with a key that is derived from the subscriber’s authentication information. At 904, the client 910 includes the challenge, response, and IP address in the DHCPREQUEST message. The DHCP server 920 forwards both the challenge and response in a

460 RADIUS\_ACCESS\_REQ message to a RADIUS server 930 in the selected service network. The RADIUS server 930 either accepts or rejects the RADIUS

request and responds accordingly at 906. If the RADIUS request is accepted, the DHCP server 920 sends a DHCPACK message at 907 and the client 910 enters a bound state. If the RADIUS request is rejected, the DHCP server 920 sends a  
 465 DHCPNACK message which informs the client 910 that the IP address that was allocated has been withdrawn.

Rather than modifying the DHCP protocol in order to establish the association between the device's MAC address and the service selection, it is advantageous to use an alternative two-step process. The registration server 162  
 470 can associate the customer's IP address (used for registration) with the subscribed service, while the configuration server 161 can associate the customer's IP address with the customer's MAC address. The servers can interact and share their associations in the registration database 163 shown in FIG. 1. Thus, the subscriber can register the service selection with the registration server which  
 475 temporarily establishes the association between the network access device's hardware address (e.g. the MAC address of the device) and the chosen service selection. The configuration server then uses the MAC address of the network access device to assign an IP address from the proper address space. FIG. 10 is a simplified timeline diagram of DHCP messages exchanged, in accordance with  
 480 such an embodiment. At 1001, the network access device 1010 registers a service selection with the registration server 1030. It is assumed that the subscriber has passed the proper authentication procedures for the particular service selected, either beforehand (e.g. through transactions directly with the service provider's network) or in the same session with the registration server. The registration  
 485 server 1030 sends some acknowledgment 1002 to the network access device 1010. At 1003, the registration server 1030 stores the selected service and associates the service selection with the hardware device address (e.g. MAC address) of the network access device 1010. After receiving the acknowledgment from the registration server 1030, the network access device 1010 releases any pre-existing  
 490 address assignment by issuing a DHCPRELEASE message at 1004. At 1005, the network access device issues a standard DHCPDISCOVER message (i.e., there is no need for the service selection id in the message set forth above). The DHCP

server 1020 receives the DHCPDISCOVER message and, at 1006, allocates an IP address from the pool of address associated with the particular service associated with the device's hardware address. At 1007, the DHCP server 1020 sends a DHCPOFFER message that includes the IP address in a field in the DHCP message. At 1008, the network access device 1010 receives the DHCPOFFER and sends out a DHCPREQUEST back to the DHCP server 1030. At 1009, the DHCP server 1030 commits to assigning the IP address to the network access device 1010, commits the binding to persistent storage, and transmits a DHCPACK message containing the configuration parameters for the device.

It is desirable to restrict access to the access network infrastructure to those network access devices that are properly registered and authenticated. In accordance with another aspect of the invention, the access network infrastructure can be configured to perform access control taking advantage of the above-described address allocation process. An access network infrastructure with broadcast capabilities will often use a protocol such as the Address Resolution Protocol (ARP) to map network layer addresses used by the packet-switched networks to the hardware addresses used in the datalink layer of the access network infrastructure. See, e.g., D. Plummer, "An Ethernet Address Resolution Protocol," IETF Network Working Group, RFC 826 (November 1982). For example, and with reference to the HFC embodiment shown in FIG. 2, the CMTS 225 has an ARP cache, which is a table of entries storing bindings between IP addresses and the hardware MAC addresses assigned to network access devices 201, 202. The ARP cache permits the CMTS to learn the correspondence between IP addresses and MAC addresses without resorting to broadcasting an ARP request. As is known in the art, the CMTS can act as a DHCP relay agent and use information in DHCP messages to populate its ARP cache. This mechanism, in combination with the DHCP address allocation process described above, can be advantageously utilized to control access to the network.

With reference to FIG. 7 (and FIG. 9), the CMTS acts as a DHCP relay agent and snoops on DHCP messages exchanged between the host acting as a DHCP client and the DHCP server. At step 707 in FIG. 7 and step 907 in FIG.

9, the DHCP server issues a DHCPACK message with configuration parameters including the committed IP address allocated to the subscriber to the particular service selected, as described above. This only occurs after the proper authentication steps have been performed. FIG. 11 is a flowchart illustrating the processing performed at the CMTS. At step 1101, the CMTS receives the DHCP message and proceeds to snoop on its contents in the process of relaying it to the proper DHCP client at step 1106. At step 1102, the CMTS determines that the DHCP message is a DHCPACK message by examining the options field of the DHCP message. At step 1103, the CMTS proceeds to read the information from the DHCPACK message, in particular the "yiaddr" and "chaddr" fields (fields 805 and 808 in FIG. 8) which indicate the assigned IP address and the hardware MAC address respectively. The CMTS updates the ARP cache to reflect the mapping of IP address to MAC address (and SID) used for communication with the subscriber. Thereafter, the CMTS permits upstream and downstream packets to and from the particular network access device based on the ARP cache entry. Where there has been a failure in authentication, this will result in a failure to update the ARP cache and in a denial of access to the access network infrastructure. The information in the ARP cache entry can also be utilized by the CMTS to monitor attempts to "spoof" the IP address of an authenticated subscriber: e.g., by refusing to forward upstream packets with a source IP address that is not associated with the proper SID or MAC address. The CMTS can set the timeout for the ARP cache entry to the same value as the timeout for the IP address specified in the DHCP exchange. If a customer subsequently releases the IP address by issuing a DHCPRELEASE message (or declines to accept the offered IP address, both at step 1104), the CMTS flushes the corresponding ARP cache entry upon receipt of the DHCP message at step 1105.

The DHCP server should be configured to ensure that every response that changes an IP address assignment or a lease on a DHCP assignment gets relayed to the CMTS. For example, a network access device using standard DHCP can send a DHCPRENEW message directly to the DHCP server. The DHCP server would respond directly to the client, and the CMTS would not

555 perform a DHCP relay function for these messages. Such direct communication between the DHCP client and server may modify information (e.g. lease time) used by the CMTS to manage the ARP cache. Therefore, it is advantageous to modify the DHCP server so that it will notify the CMTS of any changes to IP address assignment including lease time. This can be accomplished, for example, 560 by sending all responses to the CMTS to relay to the client—rather than sending them directly to the client.

It is advantageous for the access network infrastructure to support quality-of-support, in particular to differentiate service between subscribers to different services or service providers. For example, with reference to FIG. 1, a 565 subscriber to services offered by a service network 151 could get a higher share of access link capacity in the access network infrastructure than a subscriber to services offered by service network 152. Likewise, the aggregate capacity for subscribers to service network 151 may be different (e.g. higher) than aggregate capacity for subscribers to service network 152. It is preferable to avoid relying 570 on the network access devices 101...104 or the network interface units 111...114 to enforce service policies. Instead, it is advantageous for the access network infrastructure to have a policy engine, referred to herein as a policy decision point, and points at which policies may be enforced. The policy decision point, for example, could be a server in the service activation system 160 in the access 575 network infrastructure with access to the relevant registration information for subscribers. The policy decision preferably should be made at a point at which the association between the service network and the access network has been established, e.g. when the authenticated IP address is provided to the network access device as described above. The service class assignment would reflect the 580 results of negotiation between the entity operating the access network infrastructure and the entity operating the service network.

FIG. 12, for example, sets forth a timeline diagram of messages exchanged in assigning a service class to a subscriber, in the context of the particular HFC architecture described above. At 1201, the network access device 585 1210 sends the DHCPREQUEST message to the DHCP server 1250, requesting

the service-related IP address identified in a previous DHCPOFFER message. At 1202, the DHCP server 1250 commits to assigning the IP address to the network access device 1210 and transmits a DHCPACK message containing the configuration parameters for the device. At 1203, the DHCP server 1250 sends a message to a Policy Decision Point (“PDP”) 1240 authorizing assignment of a particular service class to the subscriber. The PDP 1240 transmits traffic parameters for the authorized service flow to the CMTS 1230, which receives the policy parameters at 1204 and begins the process of Dynamic Service Addition (DSA) in accordance with DOCSIS to schedule the service flow. A service flow, as defined by DOCSIS, is a unidirectional flow of packets that is provided a particular quality of service. At 1205, the CMTS 1230 sends a dynamic service addition request (DSA-REQ) message to the cable modem 1220 attached to the relevant network access device 1210. At 1206, the cable modem 1220 sends a dynamic service addition response (DSA-RSP) message after confirming that the cable modem 1220 can support the service flow. At 1207, the CMTS 1230 sends a dynamic service addition acknowledge (DSA-ACK) message after enabling transmission and reception of data on the new service flow. At 1208, the service flow has been allocated, and transmission on the new service flow has been enabled. At 1209, the network access device 1210 can begin transmitting data upstream to the CMTS 1230 which, as described above, forwards the data to the relevant packet-switched network.

Where the packet-switched network also provides for differentiation in service, e.g. based on the “DiffServ” framework, the cable modem 1220 can mark the Type Of Service (TOS) field of the packet to indicate the service class for the packet. See K. Nichols, S. Blake, F. Baker, D. Black, “Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers,” IETF Network Working Group, RFC 2474 (December 1998); S. Blake, D. Black, M. Carlson, E. Davies, Z. Wang, W. Weiss, “An Architecture for Differentiated Services,” IETF Network Working Group, RFC 2475 (December 1998), which are incorporated by reference herein. Using the policy information received from the PDP 1240, the CMTS 1230 can act as a policy enforcement

point and police the packets received from the cable modem 1220 and remark the TOS field of the packet where there is any deviation from the policy specified for the particular subscriber. Similarly, the CMTS 1230 can police service flows in  
 620 the downstream direction, again based on the policy provided by the PDP 1240.

The CMTS 1230 performs scheduling based on the policies provided by the PDP 1240. Scheduling can be based on differentiation between subscribers to different services or service providers and can also be used to ensure that reserved minimum traffic rate requirements are met (this may require  
 625 some measurement of capacity allocated to different subscribers as well as an accounting of bandwidth usage). One method of scheduling in the CMTS is to follow class based queuing (CBQ). See S. Floyd, V. Jacobson, "Link-Sharing and Resource Management Models for Packet Networks," IEEE/ACM Transactions on Networking, Vol. 3, No. 4, August 1995, which is incorporated by reference  
 630 herein. CBQ allows for support of quality-of-support and flexible link sharing. The mechanism can be used to share capacity of a link across services, protocol families and/or traffic types. It can be used to allocate "shares" to individual service providers and subdivide the share amongst the subscribers of a given service provider. For example, arriving packet flows are aggregated into classes,  
 635 each class having a "priority" and a throughput allocation. The traditional method is to use the information in the packet header, although it is possible, in the HFC architecture, to classify based on SID and the policy set up at the time the service flow is setup. A hierarchy of classes is constructed, e.g. as depicted in FIG. 13. The access link 1300 is shared between three service providers 1351, 1352, and  
 640 1353. Each service provider shares its allocation of link bandwidth among its customers, i.e., 1311, 1312, 1313 being subscribers of service provider 1351; 1321, 1322 being subscribers of 1352; 1331 being a subscriber of service provider 1353. The link scheduler may associate weights for each service provider. The service provider "weight" determines the overall share of access link bandwidth to  
 645 all subscribers of the service provider, when the link is fully utilized. The link scheduler further allocates weights to each customer of the service provider—the customer's weight determining the share of the service provider's link bandwidth

available to the subscriber. It can then be possible to “borrow” bandwidth from other service provider subscribers when the service provider’s share is not fully  
650 subscribed, as well as from other service providers when the link is not fully loaded. It is advantageous for the scheduling to provide such flexible sharing. When the link is underloaded, there is no need for any regulation of access to the HFC link by active SIDs. The scheduler can regulate a particular customer, e.g. by postponing giving grants to a SID of the customer, only when the customer is  
655 over the limit in terms of bandwidth share during the short-term interval.

The foregoing Detailed Description is to be understood as being in every respect illustrative and exemplary, but not restrictive, and the scope of the invention disclosed herein is not to be determined from the Detailed Description, but rather from the claims as interpreted according to the full breadth permitted by  
660 the patent laws. It is to be understood that the embodiments shown and described herein are only illustrative of the principles of the present invention and that various modifications may be implemented by those skilled in the art without departing from the scope and spirit of the invention. For example, the detailed description describes an embodiment of the invention with particular reference to  
665 an HFC access network architecture. However, the principles of the present invention could be readily extended to other access network architectures, such as DSL, wireless, satellite, etc. Such an extension could be readily implemented by one of ordinary skill in the art given the above disclosure.